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# Edge Segmentation of Satellite Image using Phase Congruency Model

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***Abstract*—**In this paper, we present a method for edge segmentation of satellite images based on 2-D Phase Congruency (PC) model. The proposed approach is composed by two steps: The contextual non linear smoothing algorithm (CNLS) is used to smooth the input images. Then, the 2D stretched Gabor filter (S-G filter) based on proposed angular variation is developed in order to avoid the multiple responses in the previous work. An assessment of our proposed method performance is provided in terms of accuracy of satellite image edge segmentation. The proposed method is compared with others known approaches.

***Keywords*—**Edge segmentation, Phase congruency model, Satellite images, Stretched Gabor filter

## I. Introduction

IN computer vision object detection have a significant role in image analysis. Several gradient-based edge detector methods have been developed. These methods are sensitive to edge magnitude, smoothness and magnification. To overcome these difficulties, many researchers are interested to features detection in the frequency domain. These methods are based on phase component of the images. Firstly, Oppenheim and Lim [1] prove that phase information is crucial to features perception. Then, Morrone and Burr [2] postulated formally the local energy model. From this work the local energy model has been used for edge detection, edge classification, image fusion and key point's detection. Recently, Venkatesh and Owens [3] deal the scheme of the local energy model for features extraction. These authors showed that phase congruency is proportional to local energy; therefore local maxima of phase congruency correspond to local maxima in local energy [4]. Moreover, phase congruency has been further modified by Kovesi [5], [6] and extended to two dimensions for corner and edge detection. An interesting suggestion of this model applied for corner detection is described in [7]. In literature, many others approaches based on the PC model have been reported [8], [9], and some of the mathematical properties of this model have been detailed in [10], [11].

The phase congruency model is relatively new model. It's applied in many area of image processing. In practice, it is the local energy model which has been utilized for features extraction in many ranges of images including face alignment [12], noise removal for iris image [13], Feature extraction of chromosomes [14] and ultrasonic liver characterization [15].

In the current work, we present a new application of the phase congruency model for satellite images edge segmentation. Then, instead of the use of the 2D log Gabor filter in [5], we use the 2D stretched Gabor filter, based on novel angular variation, to compute the PC map of satellite images.

The remainder of this paper is organised as follows: Section 2 introduce the concept of 2D phase congruency model used in this paper. Section 3 presents the review of multi-channel filtering for phase congruency computing. In the following section, we formalize our satellite images edge segmentation scheme. Section 5 gives some simulation results regarding the stability and the performance of the proposed approach compared with others known algorithms.

## II. 2D Phase congruency measure

The phase congruency model has also been implemented using banks of filters. This model was further modified by Kovesi in [5], [6]. An apparent problem of PC model it is a rather difficult quantity to calculate and is very sensitive to noise. In this paper, we use the measure of phase congruency in expressed by [5]

$$PC(x,y)=\frac{\sum_o \sum_s W(x)\lfloor A_{so}(x,y)\Delta\phi_{so}(x,y)-T\rfloor}{\sum_o \sum_s A_{so}(x,y)+\varepsilon} \qquad (1)$$

Where $o$ and $s$ denotes the index over orientations and scales respectively, the symbols $\lfloor\ \rfloor$ denote the enclosed quantity is equal to itself when its value is positive, and zero otherwise. $W(x)$ is the sigmoid function used to weight a phase congruency. Using the same notation in [15] let $M_{so}^{even}$ and $M_{so}^{odd}$ denotes the even-symmetric and odd-symmetric filter at scale $s$ and orientation $o$, respectively. We define the response vector given by

$$\left[e_{so}(x,y),o_{so}(x,y)\right]=\left[I(x,y)*M_{so}^{even},I(x,y)*M_{so}^{odd}\right] \qquad (2)$$

The amplitude of the response at a given scale and orientation can be expressed by

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$$A_{so}(x,y)=\sqrt{e_{so}(x,y)^2+o_{so}(x,y)^2} \tag{3}$$

And the phase angle is defined by

$$\phi_{so}(x,y)=a\tan\left(e_{so}(x,y)/o_{so}(x,y)\right) \tag{4}$$

Denote $\bar{\phi}_o(x,y)$ the mean phase angle at orientation $o$, a more sensitive phase deviation measure is given by

$$\begin{aligned}\Delta\phi_{so}(x,y)=&\cos\left(\phi_{so}(x,y)-\bar{\phi}_o(x,y)\right)\\&-\left|\sin\left(\phi_{so}(x,y)-\bar{\phi}_o(x,y)\right)\right|\end{aligned} \tag{5}$$

According to Kovesi [5], using the magnitude of dot and cross products between the weighted mean filter response vector and the individual filter response vectors at each scale, the phase deviation can be calculated directly from the filter outputs, as [15].

$$\begin{aligned}A_{so}(x,y)\Delta\phi_{so}(x,y)=&\left(e_{so}(x,y).\bar{\phi}_o^{even}(x,y)+o_{so}(x,y).\bar{\phi}_o^{odd}(x,y)\right)\\&-\left|e_{so}(x,y).\bar{\phi}_o^{odd}(x,y)+o_{so}(x,y).\bar{\phi}_o^{even}(x,y)\right|\end{aligned} \tag{6}$$

## III. Multi-channel Filtering for phase congruency computing

Multi-channel filtering is extensively used in computer vision to estimate information from images such as: phase, energy, frequency and orientation. Several filter functions such as Gabor functions, Morlet wavelet, log Gabor filters banks and stretched Gabor filters. Among these filters, the Gabor filter is most widespread. Indeed, it's have been used [16] to analyze the text image and in [17] for texture segmentation. But unfortunately, Gabor filters have numerous limitations in terms of their direct application in computer vision. First, these filters are non-orthogonal though the family forms a frame (the family is complete but redundant) [18]. Although Gabor functions are well localised, they inevitably have infinite support. Truncation is used in most practical implementations to avoid aliasing. Finally, a Gabor pair is not in quadrature as it has non-zero negative frequencies and a non-zero DC component (the cosine component does not integrate to zero) [19]. In order to overcome these drawbacks Heitger and al [20] developed the Stretched-Gabor (S-Gabor) filters. These functions have similar spatial filtering properties to the Gabor functions but zero DC mean. These filters have been used by Ben Robbins [9] to calculate 2D local energy. Recently, Ben Robbins and Owens [8] use the S-Gabor filters to extract 2D image features. More recently, the log Gabor filters has been used to compute phase congruency and detect edges [5] and corners [7]. The 2D Morlet wavelets have been used [15] in medical images to extract feature of chromosomes from 3-D confocal microscope images.

In this manuscript, based on the measure of phase congruency presented in the previous section, the 2D stretched Gabor filter is used to compute the phase congruency map of satellite images. Following the notation of [9], the S-Gabor functions are generated in the frequency domain and given in polar coordinates by
The even symmetric 2D filter component is given by

$$G(r)=e^{\left(-r^2/2\sigma^2\right)}.\cos\left(2\pi\nu_0 r\zeta(r)\right) \tag{7}$$

And the odd symmetric 2D filter is expressed by

$$G(r)=e^{\left(-r^2/2\sigma^2\right)}.\sin\left(2\pi\nu_0 r\zeta(r)\right) \tag{8}$$

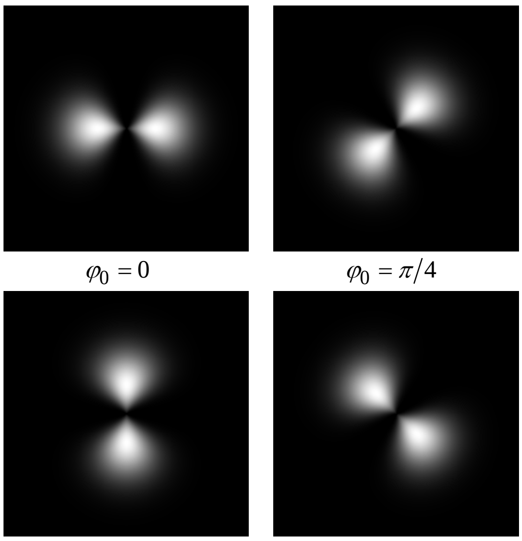
Where $\sigma$ determines the width of the Gaussian envelope, $\nu_0$ is the frequency at the origin and $\zeta(r)$ gives the frequency sweep of the filter, it is expanded as

$$\zeta(r)=0.5\,e^{-\lambda(r/\sigma)^2}+0.5 \tag{9}$$

Where $\lambda$ is chosen numerically. It is equal to 2 in this study.
Usually the two dimensional stretched Gabor filter is constructed by using a power of cosine function as angular variation.

$$\mathrm{F}(r,\varphi)=G(r).\cos^{2m}(\varphi_0-\varphi) \tag{10}$$

Where $\varphi_0$ determines the filter orientation, $m$ is a positive integer determining the orientation selectivity and $G(r)$ is the even or odd-symmetric S-Gabor function defined previously. The frequency representation of the resulting filter is shown by:



$\varphi_0=0$ $\quad$ $\varphi_0=\pi/4$

$\varphi_0=\pi/2$ $\quad$ $\varphi_0=3\pi/4$

Fig. 1 The frequency domain representation of the Stretched Gabor filter for four orientations: This representation uses as the angular variation a power of cosine.

## IV. Satellite images edge segmentation scheme

The stretched Gabor filters described in the previous section has been efficiently used to extract 2D image features (key-points) [8]. In this paper, we utilize the 2D stretched Gabor filter based on the modified angular component given in (11). The proposed method for edge segmentation of satellite images is composed by two principles steps. Firstly, we propose the use of the non linear contextual smoothing algorithm to smooth the input satellite images. Secondly, we compute the phase congruency map of the smoothed images. The principles steps for phase congruency computing in [5] are investigated.

### *A. Non linear smoothing*

Often, the real image and especially the satellite images are corrupted by many types of noise in its acquisition and transmission. In the recent years, there has been a great amount of research on images denoising or smoothing [21], [22], [23], [24], [25], [26], [27] and many technique of thresholding. In our context, several denoising algorithms are not efficient since it remove phase component of the input images. Here, we bases on contextual non linear smoothing algorithm [21]. This algorithm is based on orientation sensitive probability measure; authors incorporate contextual information through the geometrical constraints on the coupling structure.

### *B. The filter function*

To overcome some drawbacks for Gabor filter and many others filters banks; and in order to remove the multiple response of the S-Gabor filter used in [8], we propose a modified stretched Gabor filters for phase congruency map computing of satellite images. In the previous work [8], the radial variation is a stretched Gabor function and the angular variation is a power of cosine. Here, we use the same 2D radial component of stretched Gabor filters [8]. But, instead of the use of the power cosine function, we propose the modified angular component expressed by

$$R(\varphi) = \left(\cos(\varphi_0 - \varphi) + \left|\cos(\varphi_0 - \varphi)\right|\right)^{2m} \tag{11}$$

The product of angular and radial component produces the resulting 2D stretched Gabor filter used to compute phase congruency map. It is expressed by

$$F(r,\varphi) = G(r) \times R(\varphi) \tag{12}$$

Where $G(r)$ is given by

$$G(r) = e^{\left(-r^2/2\sigma^2\right)} \times \cos\left(2\pi\nu_0 r\zeta(r)\right) \times \sin\left(2\pi\nu_0 r\zeta(r)\right) \tag{13}$$

The 2D frequency representation of the proposed stretched Gabor filter is shown by the following figure

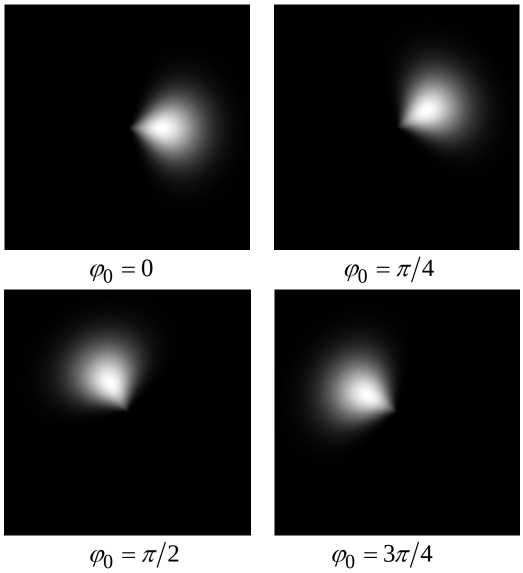


Fig. 2 The frequency representation of the proposed stretched Gabor filter for four orientations

## V. Experimental Results

We have applied the edge segmentation scheme on three satellite images with the same size *(256×256)*. In order to evaluate the proposed scheme, we have compared it with others approaches. Indeed, the Kovesi approach [5], Ben Robbins method based on stretched Gabor filter [8] and Susan method are utilized. Usually, in the literature the 2D stretched Gabor filter use the power of cosine as angular component. One of the primary motivation, we use a modified angular component (11) of the stretched Gabor filter. In fact, for the Kovesi method, we have used similar parameters in [5].

Furthermore, the proposed 2D stretched Gabor filter given by figure 2 is used to compute the 2D Phase congruency map of satellite images. These filters were constructed directly in the frequency domain as polar functions. It is characterized by two components a stretched Gabor function in the radial variation (13) and a modified power of cosine (11) in the angular direction. In the angular direction, the sharpness of the orientation $m$ was set to 2. In the radial direction, the width of the Gaussian envelope was set at $\sigma = 3$, the frequency at the origin value $\nu_0 = 0.05$ was used, and $\lambda$ was set to 2. The stretched Gabor filters is defined for four orientations and three scales. In the phase congruency measure, a noise compensation $k$ value was set to 3. The value of $\varepsilon$ was set at 0.001. For the non linear smoothing, the presented results are carried out to 9th iteration because the non linear algorithm gives bad smoothing results within several iterations. The segmented image was obtained by performing non-maximum suppression and the hysteresis thresholding of the phase congruency map. The low and high values of hysteresis thresholding are set for different methods at [0.3-0.2].

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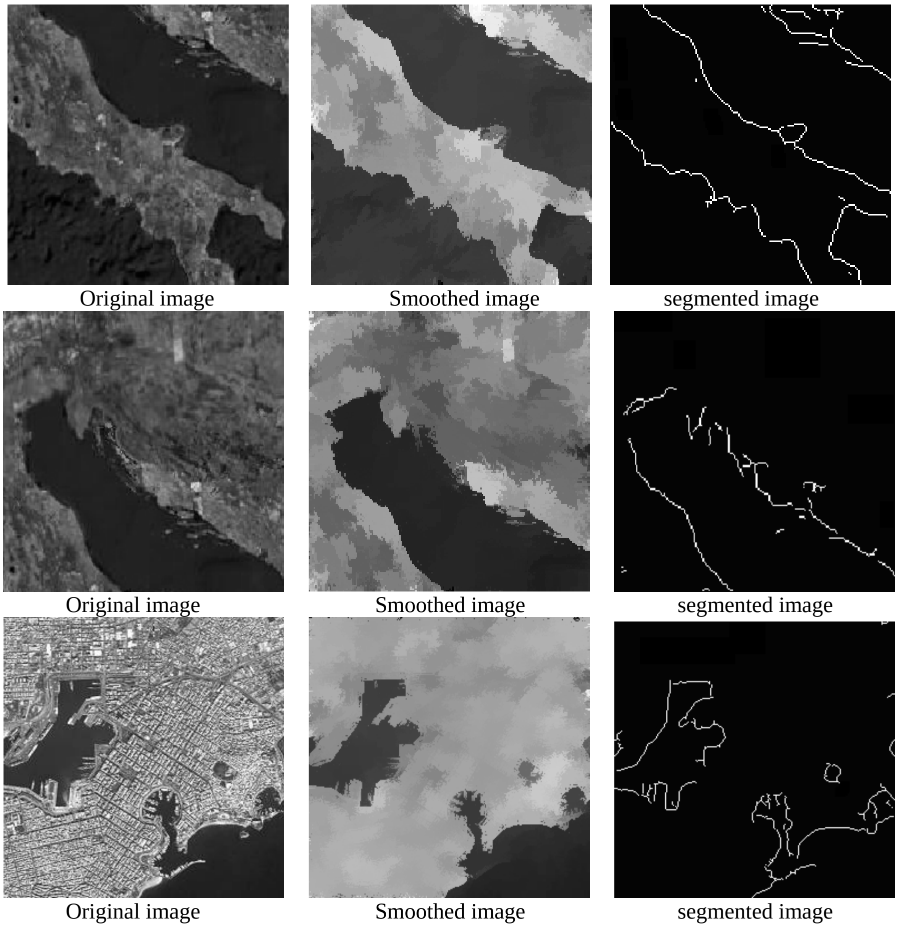


Fig. 3 The smoothed image at the 9th iteration and segmented images using the proposed method.

phase congruency images followed by hysteresis thresholding with upper and lower hysteresis threshold values fixed at phase congruency values.

## VI. Discussion

The phase congruency model is used on the wide range of images. This model suffers some drawbacks like the sensitivity to the noise and the very computational costs. While the satellite images present many types of noise in their transmissions and acquisition. This work deals the application of the phase congruency model in satellite images.

Figure 3 show the output from the proposed approach for three satellite images. Our method detects only the major boundaries, a thinned and connected edge of all satellite images. As seen in figure 4 the comparative study of the proposed approach with the traditional S-Gabor filter utilized in [8] and that based on 2D log Gabor filter [5]. We remark that the Kovesi edge detector can not find all correct edges and detect some false features. In addition, its presents many disconnected features. On the other hand, the measure of the phase congruency based on stretched Gabor filter defined by (10) produces multiple responses and presents some false detected edges. Both approaches present discontinuities of some edges.

Accordingly, for the proposed approach some details and features are smoothed out while major edges and junctions are preserved accurately. Indeed, we note that the proposed algorithm gives thinner and better connected edges than two others methods.

Figure 5 show the edge segmentation results of the proposed approach compared with Susan edge detector. Visually, the proposed method gives thinner and connected edges than Susan approach. The Susan approach remains sensitive to the choice of the thresholding value.

Accordingly, we conclude that the method based on 2D log Gabor filter is sensitive to noise than the proposed method. Additionally, the method based on stretched Gabor filter, using the power of cosine as an angular component, present multiple responses. All approaches presented here are sensitive to the choice of the low and high values of hysteresis thresholding. Here, the values of threshold are set according to the values of the phase congruency map.

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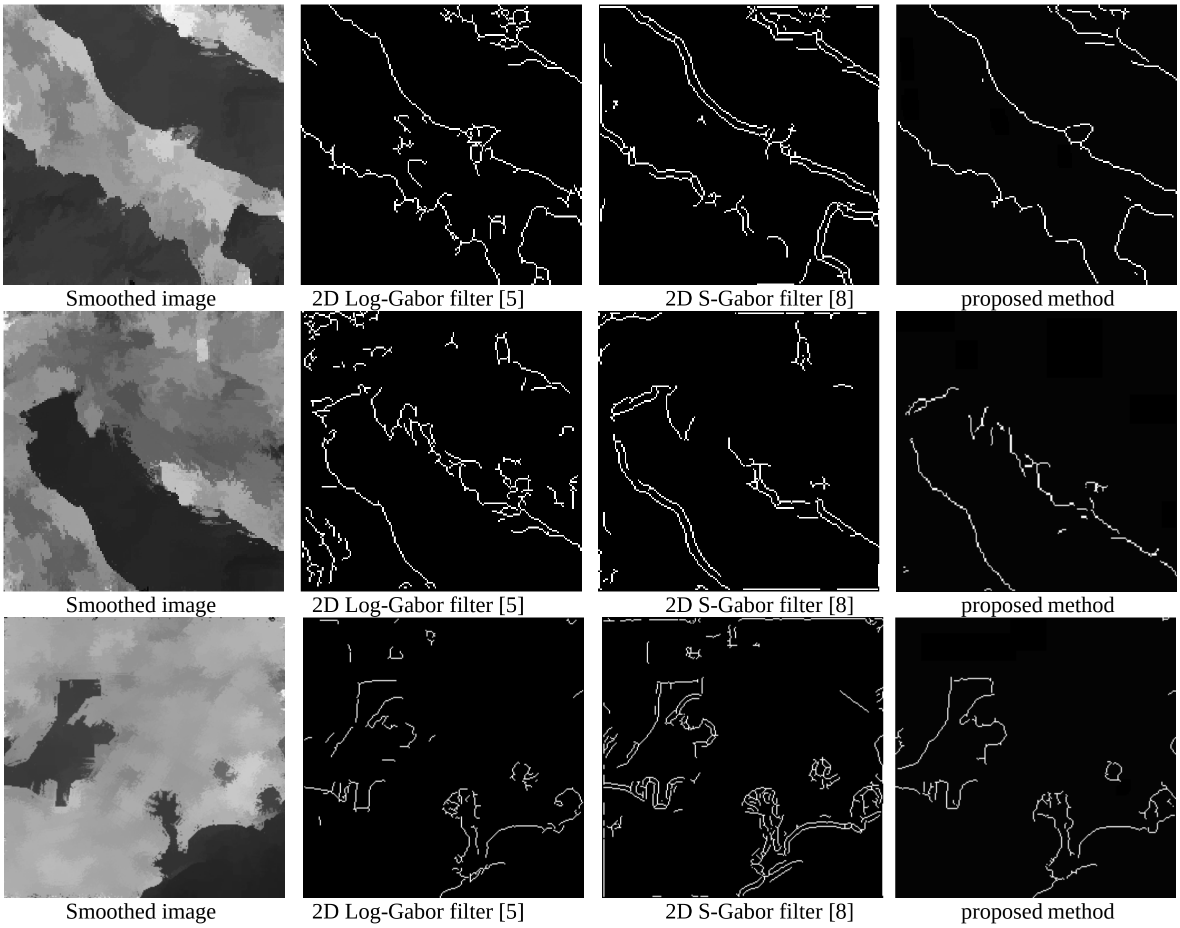


Fig. 4 Edge segmented images: Smoothed image of different algorithm is at the 9th iteration

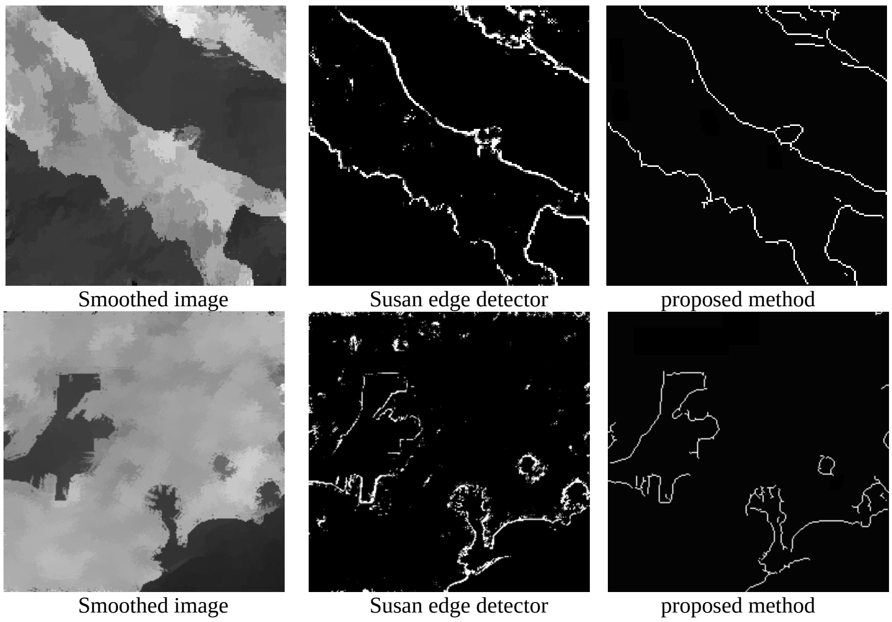


Fig. 5 Edge segmented images; Comparative study of the proposed method with Susan edge detector $(T = 40)$

## VII. Conclusion

In this manuscript, we have presented a new application of phase congruency model for edge segmentation of satellite images. The proposed approach gives better results than others approaches with which it was compared. We conclude that the choice of the filters banks for phase congruency computing remains difficult according the application. As future work, the use of the phase congruency model for many ranges of real images and texture analysis.

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